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AUTONOMOUS APPROACH AND LANDING CAPABILITY (AALC) DEMONSTRATION

Delivery Order 0018: Opportune Landing Site (OLS) Software Field Demonstration and Validation of Capability to Identify Landing Sites and Low Incidence of False Positives

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SynGenics Corporation

SEPTEMBER 2008
Interim Report

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14. ABSTRACT
The objective of the OLS Software Demonstration and Validation was to enable and demonstrate the capability to locate possible suitable landing zones (LZs) that are smooth, flat, firm, free of obstructions, and strong enough to support mobility aircraft operations. A field demonstration and assessment of the OLS runway-finding software was held in St. Clair County, IL, on 5 June 2007. The purpose of this portion of the OLS field demonstration was to assess the capability of the runway-finding software. Of the 23 software-designated sites reviewed, all were considered potentially acceptable OLSs, although they were shorter in length than what was initially sought. Of the 17 special tactics team (STT)-determined sites, 14 were considered potentially suitable. The implication is that the runway-finding software module of the OLS System may provide an excellent tool in helping the warfighter to achieve global access to the battlespace. Other modules of the system were not demonstrated. Future steps may include further scientific investigation and refinement of this software module. One issue is georegistration. That issue may provide a good candidate for future work under the OLS Technology Maturation Plan.

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1. Executive Summary

The objective of the Opportune Landing Site (OLS) Software Demonstration and Validation was to enable and demonstrate the capability to locate possible suitable Landing Zones (LZs) that are smooth, flat, firm, free of obstructions, and strong enough to support mobility aircraft operations. The Boeing Company developed the OLS system software application to aid the warfighter in achieving global access to the battlespace. The application currently comprises four separate modules of computer-coded algorithms. One module uses satellite imagery to identify candidate landing areas that are large enough, flat enough, and suitably free of vegetation, standing water, and obstacles. This module is referred to in this report as the runway-finding software. Another module uses topographic data and historical databases to determine soil type. A third module uses weather data and soil type to determine soil moisture content, and the fourth module uses soil type and moisture content to determine soil strength.

A field demonstration and assessment of the OLS runway-finding software was held in St. Clair County, IL, on 5 June 2007. The purpose of this portion of the OLS field demonstration was to assess the capability of the runway-finding software. The field reviewing team comprised personnel from the Air Force Research Laboratory (AFRL), the Air Mobility Command (AMC), the Army's Engineer Research and Development Center-Cold Regions Research and Engineering Laboratory (ERDC-CRREL), General Dynamics Advanced Information Systems (GDAIS), the Boeing Company, and SynGenics Corporation.

For the field demonstration, Boeing obtained LANDSAT imagery for St. Clair County, IL, collected in May 2007. Boeing ran the OLS “flatness” software on the LANDSAT image to determine suitable landing areas dimensioned 1,000 feet by 90 feet after the software was not able to find suitable landing sites measuring 3,500 feet by 90 feet, according to the original requirement. Boeing then provided the results of the software analysis of the region to the AMC. AMC designated a single trained Special tactics team (STT) representative to identify all suitable landing areas dimensioned 3,500 feet by 90 feet in the same area (St. Clair County, IL) using aerial photography, topographic maps, digital topographic elevation data (DTED), and other typically used means. Currently, the conventional "boots-on-the-ground" method is used by STTs to review possible landing sites. The data used by the STT representative was not of the same time frame as the satellite image, but was older by several years. On 5 June 2007, the field reviewing team visited many of the sites designated by the OLS runway-finding software in order to assess the accuracy of the software and its capability to find suitable landing sites. The team also visited 16 of the 17 sites proposed by the STT representative. The team went to 35 sites, some of which contained clusters of candidate OLSs identified by either or both methods.

Of the 23 software-designated sites reviewed, all were considered potentially acceptable OLSs although they were shorter in length than what was initially sought. Of the 17 STT-determined sites, 14 were considered potentially suitable. One of the sites appeared to cross power lines (although it was difficult to determine from the dirt road to which the team had access). Two of the sites crossed a construction site that was not reflected in the old DTED data. Additionally, one of those two also crossed a ditch (on the opposite end from the construction site location.) Adjusting the software to require a longer runway length may rule out some of the software-designated sites, but, based on the requirements made for this demonstration, all of the software-designated sites proved acceptable. The implication is that the runway-finding software module of the OLS System may provide an excellent tool in helping the warfighter to achieve global access to the battlespace. Other modules of the system were not demonstrated.

Future steps may include further scientific investigation and refinement of this software module. Additionally, the OLS Project Team continues to define potential uses for the OLS software and to consider whether it should be distributed as a package or a service and who should maintain the database of information upon which it relies, adding to and/or upgrading that database as situations change. One issue is georegistration. That issue may provide a good candidate for future work under the OLS Technology Maturation Plan.

2. Overview

The OLS Software Demonstration Plan describes a means to validate the utility and accuracy of the OLS software application to locate and evaluate natural terrain LZs for airlift aircraft. The OLS application uses satellite imagery to scan for obstacle-free, water-free and heavy-vegetation-free areas for evaluation as candidate LZs. It then uses myriad data sources to infer soil type, and it uses mesoscale atmospheric modeling and soil moisture modeling to infer soil strength. Areas that pass threshold values for openness; absence of heavy vegetation, standing water, and obstacles; smoothness; and soil strength are identified as opportune landing sites.

A proven OLS System will aid the warfighter in achieving anywhere-anytime access to the battlespace. This technology will aid in conducting military operations from semi-prepared or unprepared locations to effect a wide range of military options. Currently, these sites are evaluated physically by military personnel before the planned operations begin. These evaluations may be performed under hostile conditions. The OLS application was developed as an alternate method of site evaluation. The OLS application will initially augment these physical site evaluations by prescreening candidate areas, providing the benefits of reducing the initial search time, and limiting the number of necessary physical site evaluations to the fewest areas. As technology and sensors improve, this application is expected to eliminate the need for the physical evaluations.

A practical demonstration program highlighted the utility and accuracy of this module of the application, with final results briefed to AMC in August 2007. The final report of the demonstration and a Technology Maturation (Tech Mat) Plan were provided to AMC. The purpose of the demonstration was to exercise the OLS software with respect to a set of criteria that represents a checkpoint along the path toward a useful capability for airlift operations. This report covers a portion of the demonstration program, describing the efforts on 5 June 2007.

2.1 Summary of Approach

The purpose of this portion of the OLS demonstration was to assess the capability of the runway-finding software. The software was used to identify all suitable runways within an area of St. Clair County. In addition, a manual inspection was performed using current conventional means, that is, identification of sites by hand using satellite images and topographic maps. Sites were assigned numbers for identification. Sites identified by inspection are designated with the prefix "J", while those determined by the software are named with a "B" prefix. There is no relationship implied between sites having the same numbers but different prefixes. On 5 June 2007, the observation team drove to most sites identified and visually inspected/verified their suitability as a landing zone. Each stop was identified by its quadrant number. This report details the results of this portion of the demonstration and compares the findings of the observation team with respect to each candidate OLS visited.

The 5 June demonstration was intended to showcase the capabilities of the OLS software to the AMC staff, demonstrate the current state of the technology, and reveal the potential of the technology for further development and fielding. Further objectives were to prove that Key Performance Parameters (KPPs) and exit criteria for the OLS software demonstration and validation program have been met and to lay the foundation for the technology maturation and risk-mitigation way forward. The purpose of this portion of the OLS demonstration was to assess the capability of the runway-finding software

2.2 Identifying Candidate OLSs

The OLS algorithms make some specific assumptions about the physics of reflected electromagnetic radiation to find suitable landing sites. Appreciating these assumptions is important in understanding the

capabilities and limitations of the application. Multispectral and hyperspectral satellite imagers measure the electromagnetic radiation emitted from the sun and reflected by a given area (pixel) of the earth's surface. The reflected component also includes atmospheric scattering of solar radiation, and, as the spectra approaches the IR spectral region, the radiation at the sensor includes earth- and atmospheric-emitted radiation. This radiation is formatted by the imager into separate images based on the wavelength of the radiation.

The OLS algorithms are based on the assumption that variations of the earth's surface reflectance are caused by physical (spatial) and material (spectral) characteristics, which can be used to discriminate the spatial and spectral properties of the terrain for a given area (pixel). These variations are used to identify standing water, areas containing heavy vegetation (high chlorophyll), and uneven terrain (combined spatial/spectral inhomogeneity). Conversely, areas with highly uniform reflectance (spatial and spectral homogeneity), are assumed to be flat areas of like material substance (dirt, grass, rock, etc.). The algorithms reject areas with large variations in reflectance, such as those caused by sharp contrast between the asphalt of a road or runway and the surrounding soil or vegetation; the OLS application looks solely for areas of homogeneous natural terrain. This report details the results of this portion of the demonstration and compares the findings of the observation team with respect to each candidate OLS visited.

The red rectangle on the map below indicates that portion of St. Clair County in which the demonstration took place.

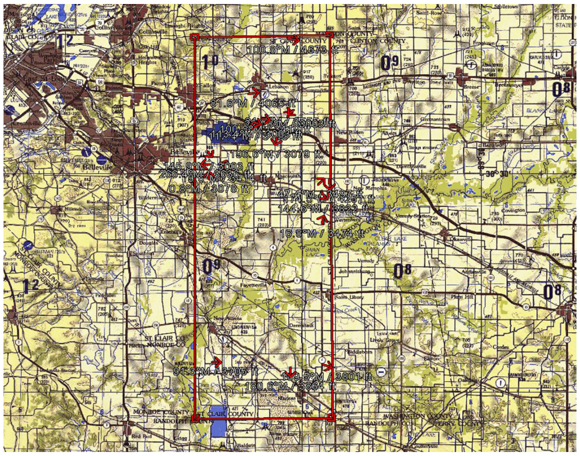

Figure 1. Demonstration Area within St. Clair County

3. Methods, Assumptions, and Procedures

It was agreed that the objective of the OLS Software Demonstration and Validation Program would be shown to have been met if the team were to demonstrate that the documented exit criteria were met. The purpose of this portion of the demonstration was to assess the OLS Software against two performance criteria, one of which was an exit criterion and a KPP:

- KPP P01: Capability to identify suitable landing sites in a specified area, given that suitable landing sites exist. Suitable is defined as having an area of the specified dimensions that is flat and free of obstacles, standing water, and heavy vegetation. Bearing strength is not a consideration for suitability in this context. Exit criterion: at least 50 percent of OLSs found. Objective: 100 percent.
- P03: Low incidence of false positives. Probability of designating an unsuitable landing site as a suitable OLS—a measure of accuracy expressed as the percentage of OLSs identified by the software that were unsuitable. Suitability as defined for this criterion excludes bearing strength. The value with respect to this desirement was to be assessed through comparison of the software analysis results with field inspection and observation results for St. Clair County. The goal was 0 percent. No upper bound was set at this stage.

Results are highlighted in Section 4. Results. KPPs P01 and P03 comprised the focus of the 5 June effort. Boeing obtained LANDSAT imagery for St. Clair County collected in May 2007. Boeing ran the OLS “flatness” software on the LANDSAT image and determined suitable landing areas dimensioned 1,000 feet by 90 feet. Boeing used those dimensions with AMC approval, after reporting that the software did not find any suitable landing sites 3,500 feet in length. Boeing then provided the results of the software analysis of the region to AMC.

In parallel with the software analysis, AMC tasked a representative of a STT, to identify all suitable landing areas dimensioned 3,500 feet by 90 feet in St. Clair County using aerial photography of the same area as the LANDSAT imagery, topographic maps, DTED, and other means typically used by STTs. This method is henceforth referred to as "inspection". The data used by the STT representative was not of the same time frame as the satellite image, but was older by several years. For example, MidAmerica Airport was under construction in the STT data, yet was operational by the time the test was conducted. The STT found OLSs by inspection in only eastern St. Clair County, looked for OLSs measuring 3,500 feet by 90 feet, and found some longer ones as well.

An AMC-designated referee was tasked to compare the software results with those of the STT representative using inspection and to calculate the percentage of correct sites (P01) and the incidence of false positives (P03). Other participants in the demonstration included representatives of AMC, AFRL/RBCC, GDAIS, SynGenics, ERDC-CRREL, and the Boeing Project Manager. They confirmed sites by observation. AFRL/RBCC representatives along with ERDC-CRREL served as impartial obervers and adjunct referees. SynGenics served as observer and recorder, and the AMC representative was the photographer. As required by the Demonstration (demo) Plan, the team obtained vantage points as close as possible to the location of the alleged OLS and ascertained by observation whether the site was a suitable LZ. The percentage of suitable LZs was to be recalculated based on these findings. LZs identified by the software, missed by inspection, but subsequently confirmed by observation would contribute to both the numerator and the denominator of this calculation. The software performance was to be considered successful if it found at least 50 percent of the suitable sites.

Although not a KPP for the demonstration, a low incidence of false positives was desired. A false

positive occurs when the software designates an area as a suitable OLS when, in fact, it is unsuitable. The occurrence of false positives would be calculated based on the comparison of software-identified LZs with inspection and observation results.

4. Results and Discussion

The demonstration team followed the Demonstration Plan as detailed in the Demo Plan section 5.1 except that they visited nearly every site found by either the software or the AMC-trained individual, the STT representative. Exception: The team visited only eastern St. Clair County.

- KPP P01: Capability to identify suitable landing sites proved difficult to quantify because it was unknown how many suitable sites exist in the region chosen for the demonstration of this desirement. OLS-MS identified 40 sites, whereas an individual using the standard manual method identified only 17 sites in the region. It could be argued that the software scored 235 percent. While the exact score is unknown, there is agreement that the exit criterion of at least 50 percent was certainly exceeded, and it could be argued that the objective of 100 percent was met. The lesson learned is that properly defining the measurand and the method of collecting the data to support quantification against that measurand is important.
- P03: Incidence of false positives was 0, meeting the objective.

The following pictures depict sites visited. They are listed in the order visited. Table 1, OLS Sites, summarizes the visits. Information in each header includes the site designation; coordinates at the northwest corner of the landing zone; runway magnetic heading (degrees); and length (feet). Pictures comprise 1) the National Geographic map, 2) photo(s) of the field, 3) orthophotoquad (for J numbers), 4) OLS software output. Text reflects findings of the observation team concerning the site. The runway-finding software identified 40 candidate LZs. Some included clusters of possible runways 1,000 feet or longer, for a total of 54 potential OLSs. The inspection method identified 17 possible runways that were at least 3,500 feet long. Of the 16 STT-determined sites visited, 13 were considered potentially suitable. One of the sites appeared to cross power lines (although it was difficult to determine from the dirt road to which the inspection team had access). Two of the sites crossed a construction site that was not reflected in the old DTED data. Additionally, one of those two also crossed a ditch on the opposite end from the construction site location. The combined results of the evaluation for both capability to identify landing sites and the occurrence of false positives indicated that the runway-finding software performed very well in the portions of the demonstration that have been completed and, in combination with other tools, could provide an excellent means of finding potential OLSs.

Table 1 indicates sites that the team visited and documented, in the order visited.

Table 1: OLS Sites

Visit	J Number	B Number	Viable OLS?	Page Number
1		B1: 38º 38' 04.53" N 89º 47' 01.88" W, 180|360	Yes	6
2		B2: 38º 37' 8.31" N 89º 41' 19.86" W, 180|360	Yes	6–7
3		B3: 38º 33' 31.54" N 89º 42' 34.80" W, 180|360, 3500 ft.	Yes	8
4	J15: 38° 39' 9.6" N 89º 45' 16.4" W, 100|280, 4600 ft.	B28: 38° 39' 18.65" N 89° 46' 54.82" W, 90|270	Yes	9
5	JX1: 38º 33' 43.4" N 89º 48' 24.2" W, 100|280, 3419 ft.			9–10
6	J8: 38° 33' 35.93" N 89º 49' 5.34" W, 120|300, 3118 ft. JX2: 38º 33' 35.5" N 89º 49' 4.5" W, 110|290, 3003 ft.		No	10–12

Table 1: OLS Sites				
Visit	**J Number**	**B Number**	**Viable OLS?**	**Page Number**
7	J7: 38º 31' 34.7" N 89º 52' 55.4" W, 150|330, 3000 ft.		Yes	12–13
8	J5: 38º 30' 09" N 89º 52' 47" W, 180|360, 3100 ft. JX3: 38º 31' 10.49" N 89º 51' 24.57" W J4: 38º 30' 39.1" N 89º 53' 29.1" W, 90|270, 3600 ft. J5: 38º 30' 09" N 89º 52' 47" W, 180|360, 3100 ft. J6: 38º 35' 29.57" N 89º 29' 19" W, 80|260, 4000 ft.	B5: 38º 30' 34.55" N 89º 51' 21.91" W, 180|360 B4: 38º 31' 10.49" N 89º 51' 24.57" W, 90|270, 1000 ft. B6: 38º 30' 04.64 N 89º 51' 51.68" W, 180|360	Yes	13–17
9	J13: 38º 29' 39.3" N 89º 42' 44.3" W, 174º, 4200 ft. J16: 38º 29' 16.4" N 89º 43' 40.4" W, 47º, 3500 ft. J17: 38º 28' 46.6" N 89º 43' 23.1" W, 144º, 3800 ft.	B24: 38° 25' 16.47" N 89° 47' 15.59" W, 060|240 B29: 38° 31' 26.06" N 89° 47' 22.24" W, 090|270 B32: 38° 30' 32.13" N 89° 43' 32.47" W, 090|270 B33: 38° 30' 23.38" N 89° 43' 32.14" W, 090|270	Yes	17–22
10	J11: 38º 33' 48.4" N 89º 48' 24.2" W, 100|280, 3500 ft. J12: 38º32'29.3" N 89º47'5.4" W, 196º, 3100 ft.	B10: 38º 32' 34.64" N 89º 46' 21.88" W, 180|360	Yes	22–25
11		B13: 38° 22' 52.29" N 89° 48' 3.21" W, 360|180 B14: 38° 22' 54.14" N 89° 46' 4.61" W, 360|180	Yes	25–26
12	J2: 38° 16' 43.1" N 89° 45' 57" W, 180|360, 3800 ft.		Yes	27–28
13	J14: 38°16'42.8" N 89°42'32.3" W, 109°, 3800 ft.		Yes	28–29
14		B16: 38° 17' 34.78" N 89° 43' 26.76" W, 180|360	Yes	29–31
15		B37: 38°20'49.33" N 89°48'18.24" W, 90|270	Yes	31–32
16		B36: 38° 23' 16.01" N 89° 54' 27.38" W, 90|270	Yes	32
17		B35: 38°24'37.58" N 89°48'35.72" W, 90|270.	Yes	33

Visit 1—B1: 38º 38' 04.53" N 89º 47' 01.88" W, 180|360

B1 was deemed a good OLS.

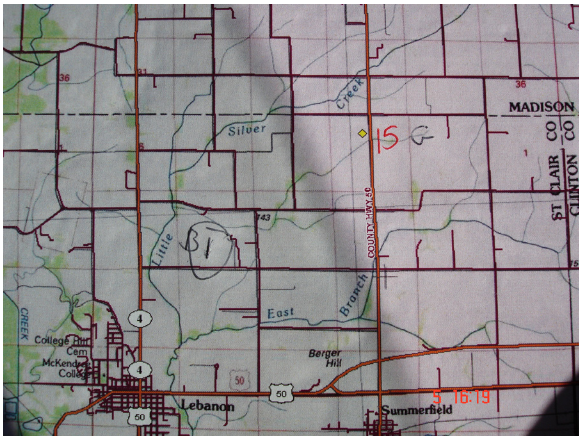

Figure 2. B1 Shown on Map

Figure 3. B1

Figure 4. B1 Another view

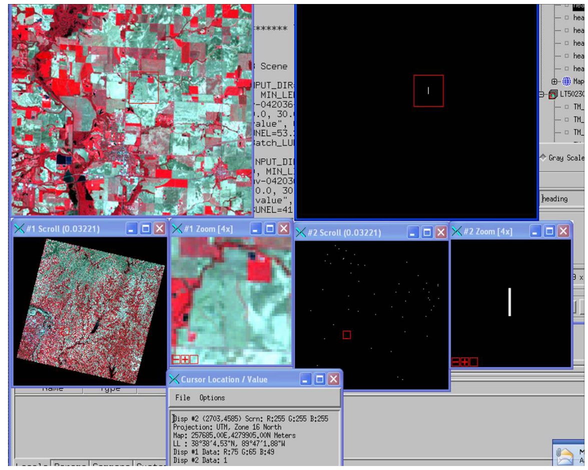

Figure 5. B1 Software Output

Visit 2—B2: 38º 37' 8.31" N 89º 41' 19.86" W, 180|360

B2 was very good. It could be oriented 90|270 or 180|360 degrees. A good approach was noted. The STT representative said he did not find it because it was an east-west runway that extended beyond the eastern edge of the area of consideration.

Figure 6. B2 Shown on Map

Figure 7. B2 (a)

Note: Looking from End of Runway

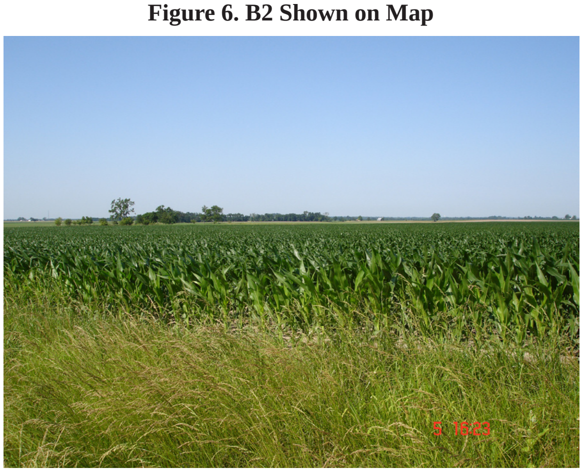

Figure 8. B2 (b) Another View

Figure 9. B2 (c) From Another Direction

Figure 10. B2 (d) Acceptable Approach

Figure 11. B2 (e)

Figure 12. B2 (f)

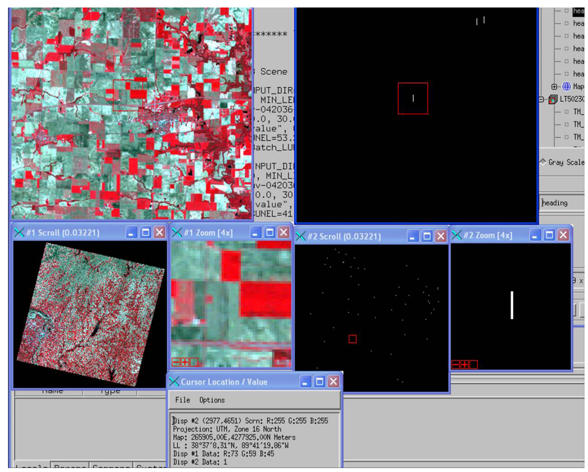

Figure 13. B2 Software Output

Visit 3—B3: 38º 33' 31.54" N 89º 42' 34.80" W, 180|360

B3 was also a good OLS.

Figure 14. B3 Shown on Map

Figure 15. B3

Figure 16. B3 Another View

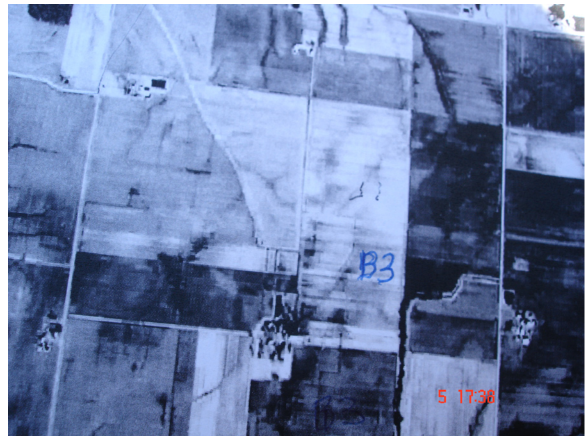

Figure 17. Orthophotoquad of B3

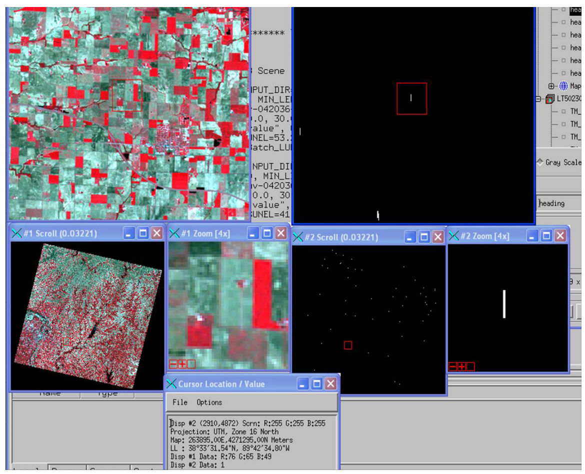

Figure 18. B3. Software Output

Visit 4—J15: 38º 39' 9.6" N 89º 45' 16.4" W, 100|280, 4673 ft.

B28: 38° 39' 18.65" N 89° 46' 54.82" W, 90|270

These runways are both oriented roughly east-west and are equivalent in terms of landing suitability. J15 and B28 are located approximately one field apart.

Figure 19. B1, and J15 As Shown on Map

Note: See red 15

Figure 20. J15

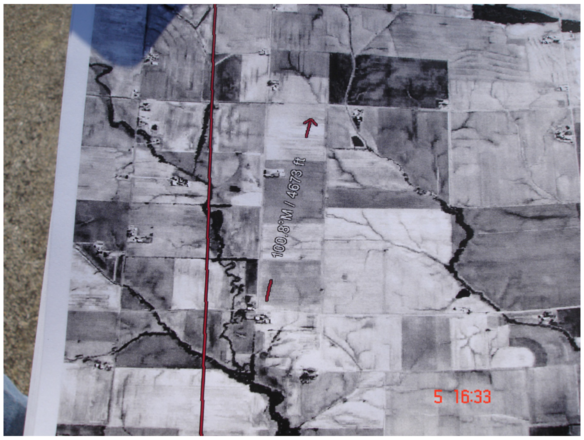

Figure 21. Orthophotoquad of J15

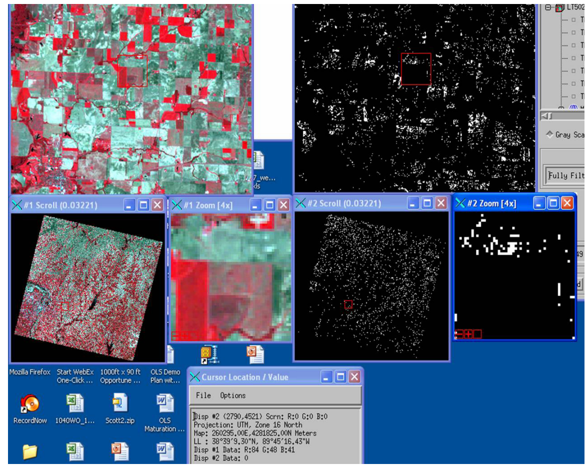
Figure 22. J15 Software Output

Visit 5—JX1: 38º 33' 43.4" N 89º 48' 24.2" W 110|280, 3419 ft.

JX1 is parallel to JX2 and J8. See Visit 6.

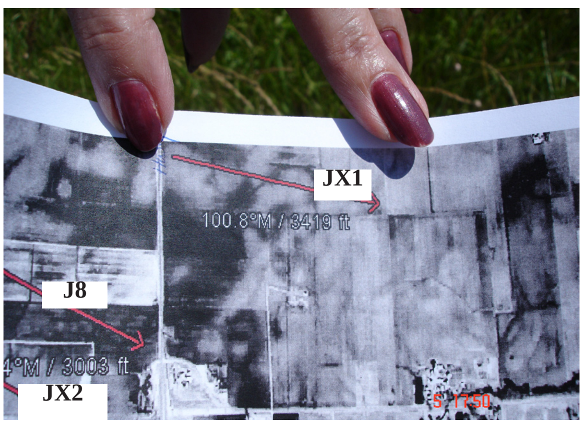

Figure 23. JX1 Shown on Map.
Note: Fingers Point to the OLS

Figure 24. JX1

Figure 25. JX1 From Another Direction

Figure 26. JX1 Another View

Visit 6—J8: 38° 33' 35.93" N 89° 49' 5.34" W, 120|300, 3118 ft.

JX2: 38º 33' 35.5" N 89º 49' 4.5" W, 110|290, 3003 ft.

These areas are under construction. There is a ramp from I-64 into what will be Hayden Retail Office Park. The construction began after the image was taken to identify the site; so it is reasonable that the STT would not have ruled the site out because of construction. However, JX2 crosses a ditch, which makes the site unacceptable (see Figure 30), both because of the ditch and because of working with old data which did not show the construction site. The STT affirmed that he took a chance on this one, thinking the ditch might be a road. A higher resolution image would have revealed the truth, "Which is why you put boots on the ground," the SST commented. This software output shows the OLS crossing the runway at MidAmerica Airport, whereas Figures 32. 34, and 36 show that it does not, illustrating the georegistration problem. Figure 32 shows that the OLS approaches the airport runway.

Figure 27. J8 and JX2
Note: Pointing to J8

Figure 28. J8

Figure 29. J8 A Closer View

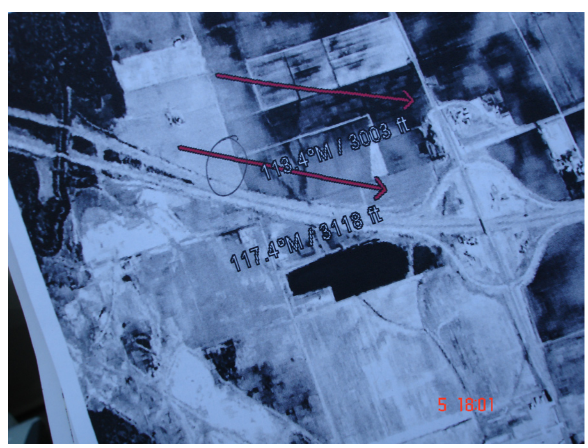

Figure 30. J8 and JX2
Note:Runway Bottom Arrow Indicates Area in Construction Site

Figure 31. JX2 (a)

Figure 32. JX2 (b)

Figure 33. JX2 (c)

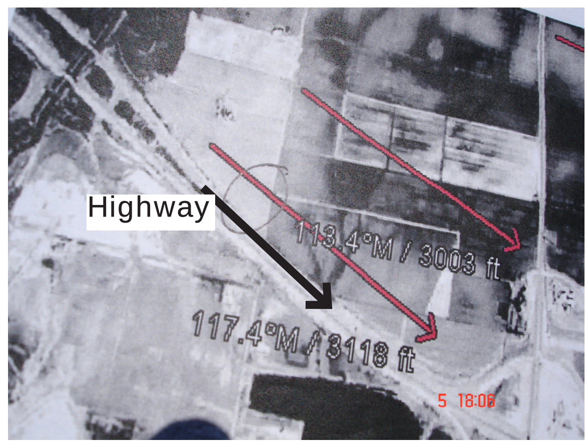

Figure 34. JX2 Repeat of Orthophotoquad

Figure 35. JX2 (d)

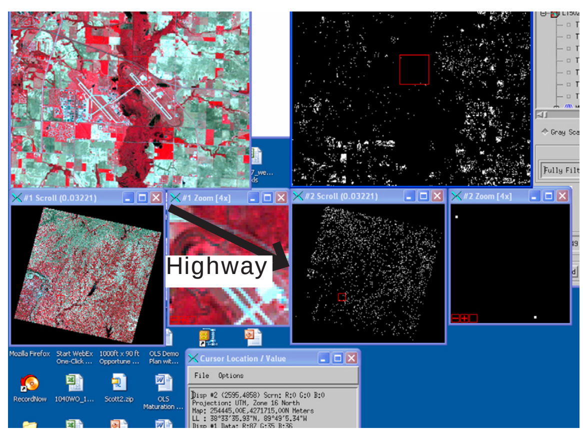

Figure 36. J8

Note: Software Output Falsely Indicating OLS Runway Crossing at MidAmerica Airport, an Illustration of Geo-registration Problem

Visit 7—J7: 38º 31' 34.7" N 89º 52' 55.4" W, 150|330, 3000 ft.

The site has a ditch, but the OLS runs east of the ditch. A house is situated the corner of the LZ area, but neither the ditch nor the house renders the area unacceptable.

Figure 37. Map Showing Location of J7

Figure 38. J7

Note: Picturing OLS Running East of the Ditch and Therefore Acceptable

Figure 39. J7 Another View

Figure 40. J7 A Different Perspective

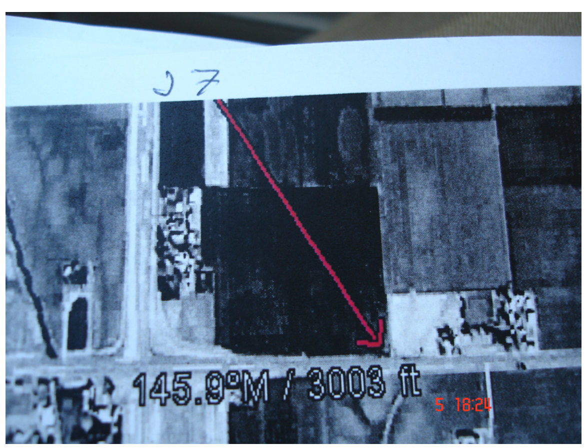

Figure 41. Orthophotoquad of J7

Note: The site has a house at the corner of the LZ area, but still the area is acceptable

Visit 8—J5: 38º 30' 09" N 89º 52' 47" W, 180|360, 3100 ft.

B5: 38º 30' 34.55" N 89º 51' 21.91" W, 180|360
B4: 38º 31' 10.49" N 89º 51' 24.57" W, 90|270, 1000 ft.
B6: 38º 30' 04.64 N 89º 51' 51.68" W, 180|360
JX3: 38º 31' 10.49" N 89º 51' 24.57" W, 180|360
J4: 38º 30' 39.1" N 89º 53' 29.1" W, 90|270, 3600 ft.
J5: 38º 30' 09" N 89º 52' 47" W, 180|360, 3100 ft.
J6: 38º 35' 29.57" N 89º 29' 19" W, 80|260, 4000 ft.

Sites B4, B5, B6, JX3, and J4–J6 were all very close together. The software-identified sites might have been missed by the STT representative because he was looking only for areas at least 3,000 ft. long. J4 is one of the OLSs the STT representative found on his way to work and was not among the OLSs that he found in his workbook. The STT representative says the best way to land is on a 180º heading. B6 is only 1,000 to 2,000 feet. The runway-finding software did not like the creek or dip at the south end. The Boeing PM pointed out the dip at the far end of the runway and questioned whether the dip is why the software rejected this as a candidate LZ when it was looking for only 1,000 feet.

J4 is not precisely the same as B5. It is in the same field but on the other side of the creek. The team did not find OLSs west of these sites because of the boundary of the search space. J7 has a ditch, but the OLS runs east of the ditch. It is nearly the same as B4. One team member observed that J7 is dangerously close to the tree line, which is on the other side of the road and not very visible in either image. The photos of B4, B6, and JX3 washed out due to a camera malfunction; hence, there is no documentation of B4–B6. All were good sites. B4 and J7 align, B5 and J4 align, and B5 and J6 align.

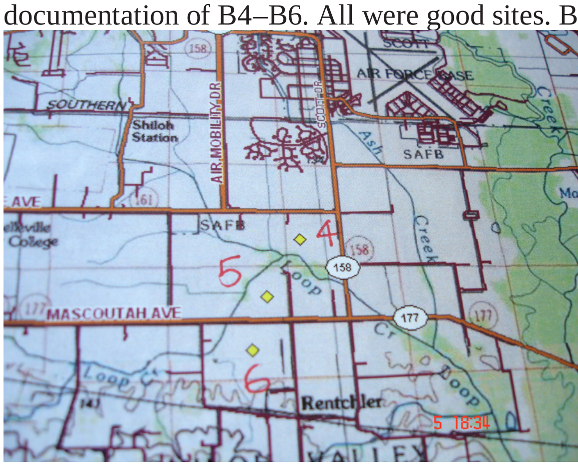

Figure 42. J4, J5 and J6 Shown on Map

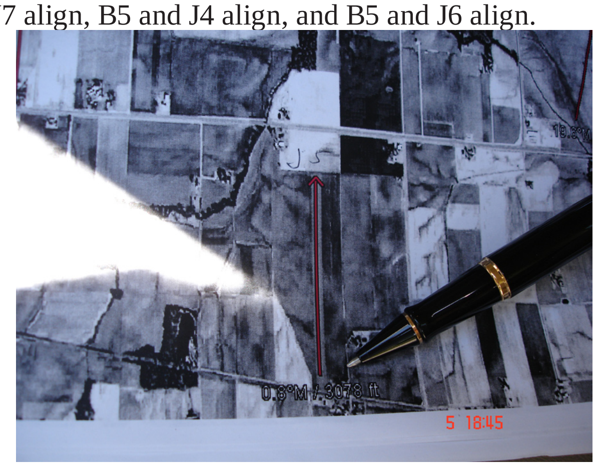

Figure 43. J5 Orthophotoquad


Figure 44. J5 A Good OLS


Figure 45. J5 Area

Figure 46. J5 Another View

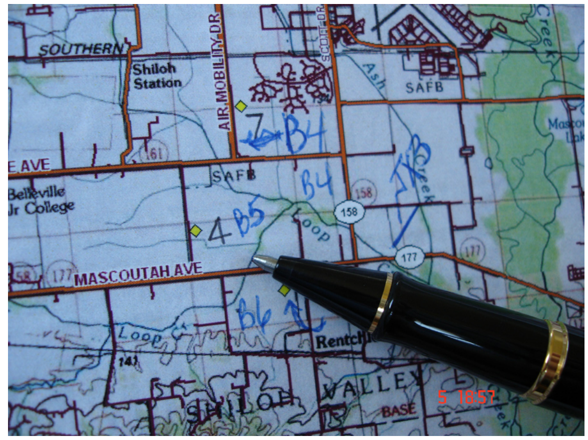

Figure 47. Map showing B4, B5, B6, JX3 Areas
Note: Focus Is on B5, Section 4

Figure 48. B5 Similar to J4
Note: Different Part of Same Field

Figure 49. B5 Looking North

Figure 50. Map Showing OLSs B4, B5, and B6

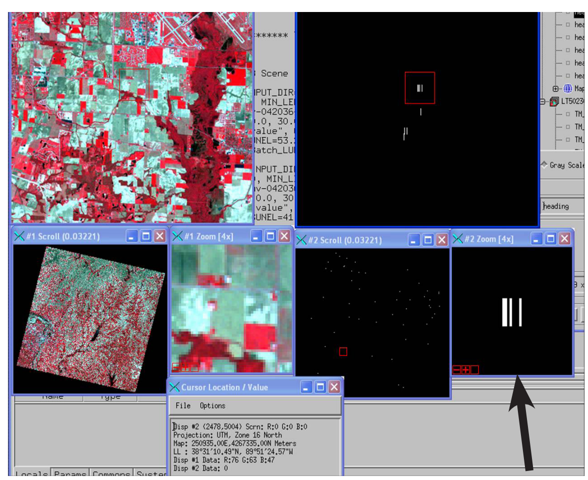

Figure 51. OLS Software Image of B4 or JX3.
Note: Software Utility Indicates a Cluster.

Figure 52. Magnified Image of B4 or JX3

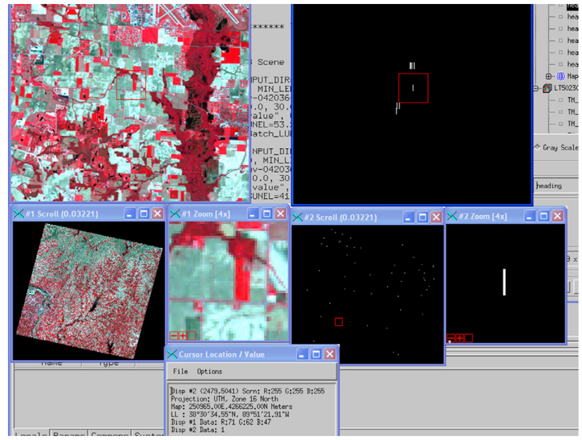

Figure 53. B5 Software Output

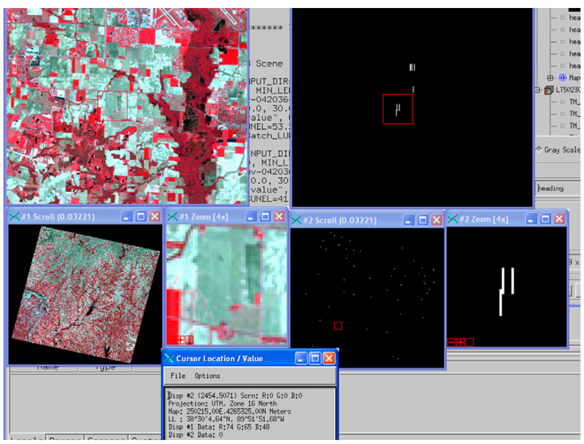

Figure 54. B6 Software Output

Figure 55. Map of J4, J5, and J6 (Repeated from P. 15)
Note: J7 Indicated by Arrow

Figure 56. Map of Shiloh Valley Area, J4, J5, J6, JX3, B4, B5, B6, and B30

Figure 57. J4 Across the Creek from B5

Figure 58. J4 Another View

Figure 59. J4 A Different Perspective.

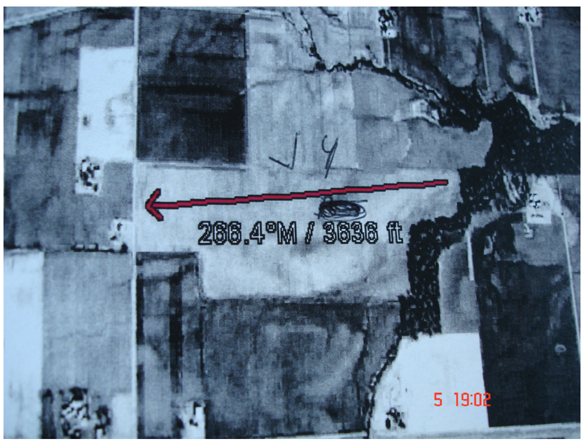

Figure 60. Image of J4


Figure 61. J4, J5, J7, and JX3 Orthophotoquad

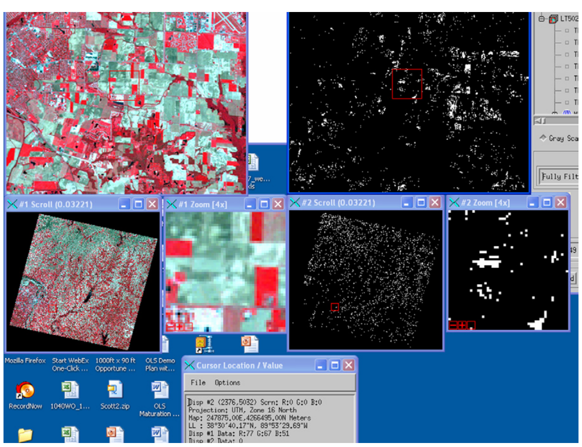
Figure 62. J4 Software Output

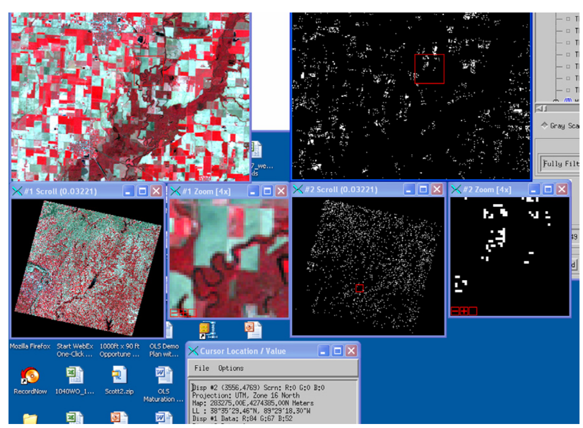
Figure 63. J6 Software Output

Visit 9—B24: 38º 25' 16.47" N 89º 47' 15.59" W, 060|240

B29: 38° 31' 26.06" N 89° 47' 22.24" W, 090|270

B32: 38º 30' 32.13" N 89º 43' 32.47" W, 090|270

B33: 38º 30' 23.38" N 89º 43' 32.14" W, 090|270

J13: 38º 29' 39.3" N 89º 42' 44.3" W, 174º, 4200 ft.

J16: 38º 29' 16.4" N 89º 43' 40.4" W, 47º, 3500 ft.

J17: 38º 28' 46.6" N 89º 43' 23.1" W, 144º, 3800 ft.

Areas B24, B29, B32, B33, J13, J16, and J17 are quite near each other and so are grouped here. B17, J13, J16 and J17 are near Miscoutah.

Figure 64. Map showing B24, B32, B33, J13, and J16


Figure 65. Orthophotoquad of J13, J16, and J17

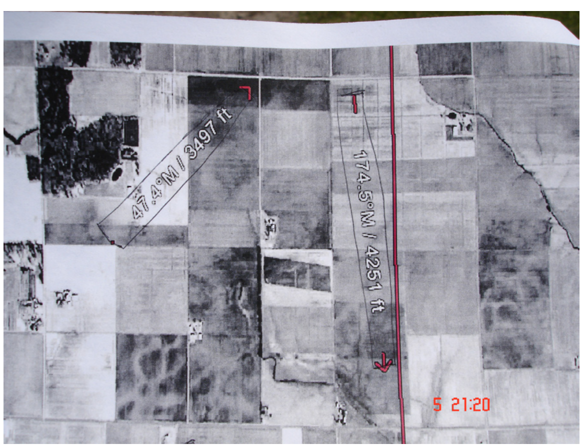

Figure 66. Orthophotoquad of J13 and J16

Figure 67. J16 (a), J13, J17, B24, B29, B32, and B33
Note: Sites are close to each other

Figure 68. J16 (b) Another View

Figure 69. J16 (c)

Figure 70. J16 (d) From Other End

Figure 71. J16 (e) A Different View

Figure 72, J16 (f) Another View

Figure 73. Orthophotoquad of J17

Figure 74. J17 (a)

Figure 75. J17 (b) A Different View

Figure 76. J17 (c)

Figure 77. J17 (d) Another View

Figure 78. J17 (e)

Figure 79. J17 (f)

Figure 80. J17 (g)

Figure 81. Orthophotoquad Showing J13, J16, J17

Figure 82. B29

Figure 83. B29 Another View

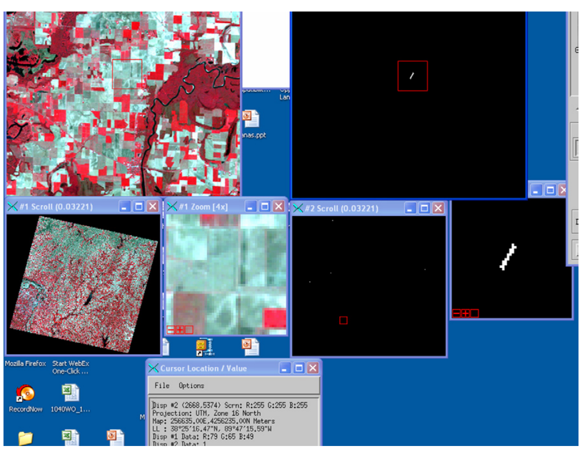

Figure 84. B24 Software Output

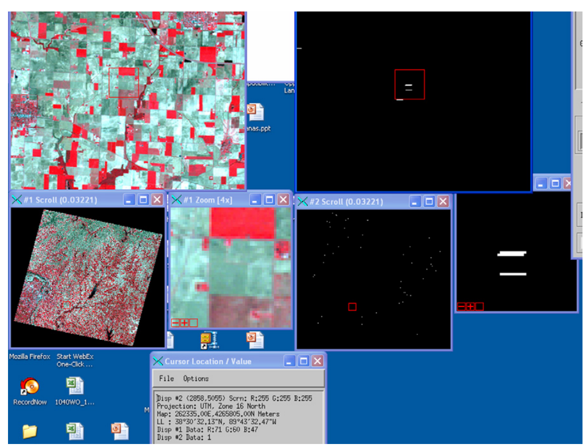

Figure 85. B32 Software Output

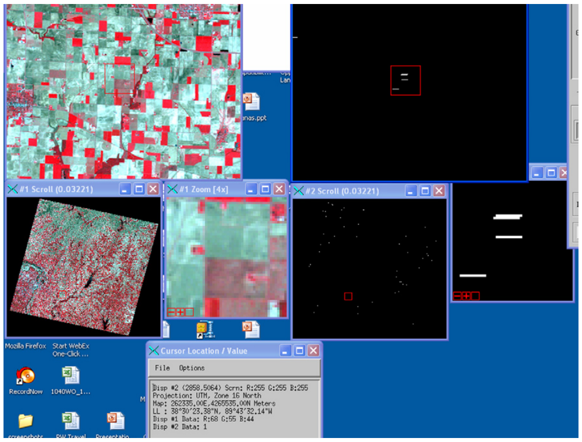

Figure 86. B33 Software Output

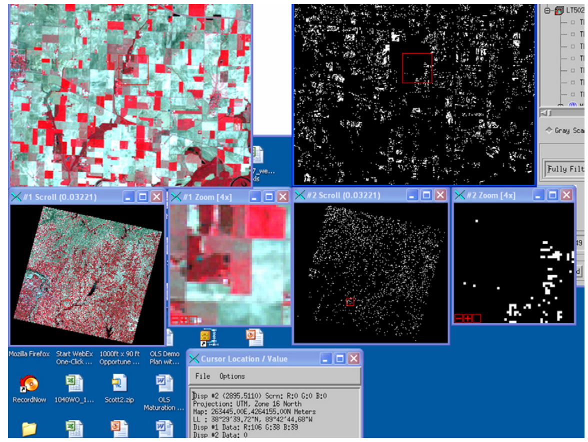

Figure 87. J13 Software Output

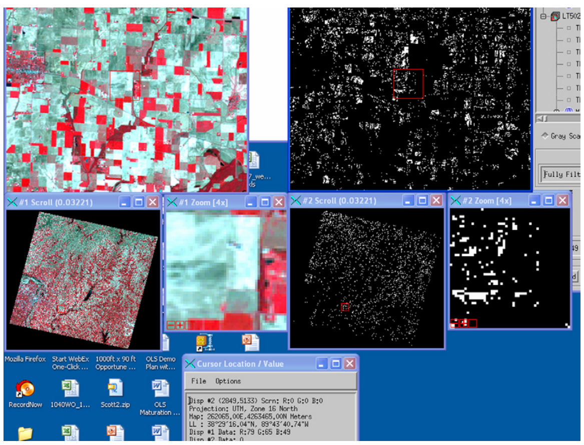

Figure 88. J16 Software Output

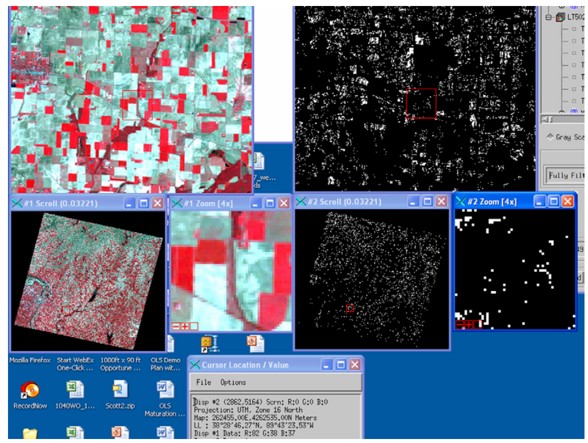

Figure 89. J17 Software Output

Visit 10—J11: 38º 33' 48.4" N 89º 48' 24.2" W, 100º, 3500 ft.
J12: 38º32'29.3" N 89º47'5.4" W, 196º, 3100 ft.
B10: 38º 32' 34.64" N 89º 46' 21.88" W, 180|360

J11 and J12 are near B10 along with J8. JX1 and JX2 are parallel to J8. J11 parallels the road on which the team stood. The church was photographed in the wrong direction at first. The team was initially concerned that the possibility existed that the OLS was crossed by power lines. They could not confirm from the roadway, but ultimately deemed the site acceptable based on the orientation of the OLS. The SynGenics representative asked why the software did not find the field photographed. It turned out that there was a six-inch high patch of vegetation in part of the area. J12 is north-south, parallel to the road, and is a good site.

Figure 90. J11 and J12 Shown on Map

Figure 91. J11 (a)
Note: Shown Here Near B10, J8, and J12

Figure 92. J11 (b) A Different View

Figure 93. J11 (c) Another View

Figure 94. J11 (d) A Different Perspective

Figure 95. J11 (e)

Figure 96. J11 (f) A Different View

Figure 97. J11 (g)

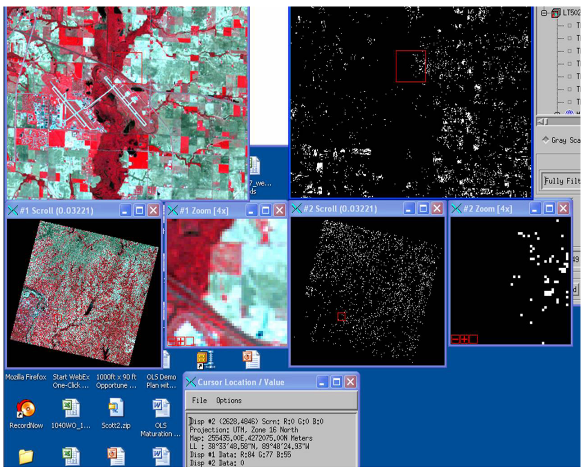

Figure 98. J11 Software Output

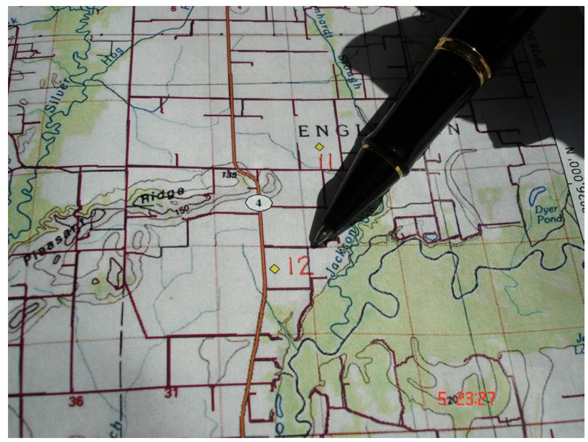

Figure 99. J12 Shown on Map

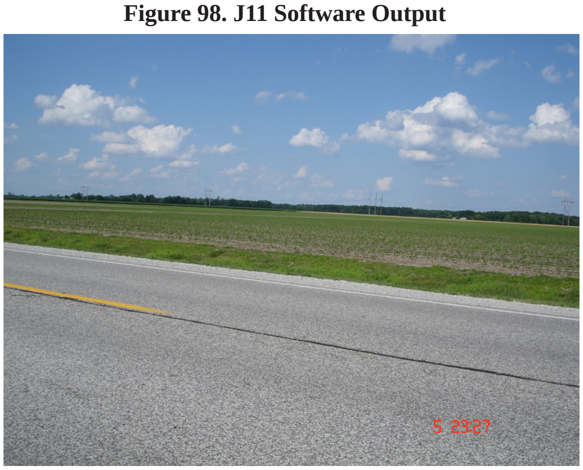

Figure 100. J12 Parallel to Road.

Figure 101. J12 Paralleling Road

Figure 102. J12

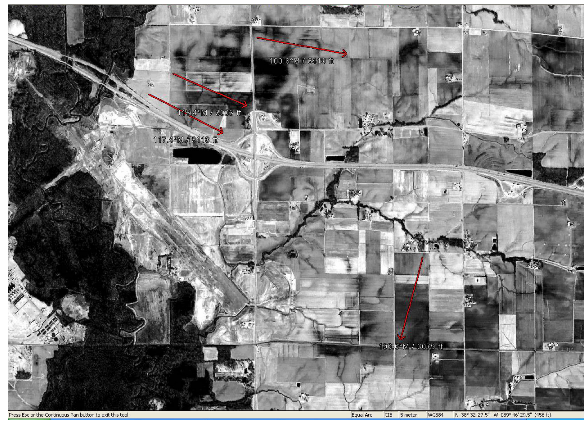

Figure 103. Orthophotoquad of J12

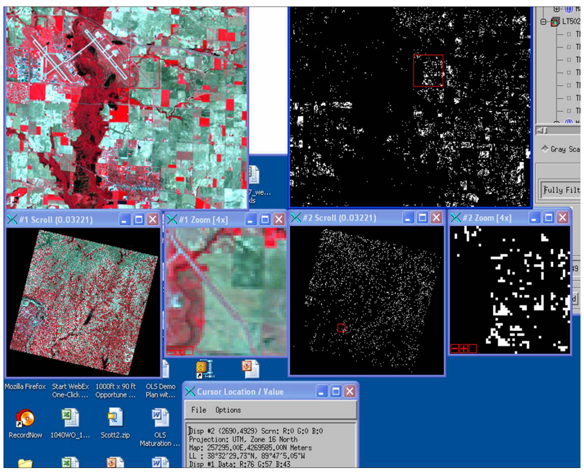

Figure 104. J12 Software Output

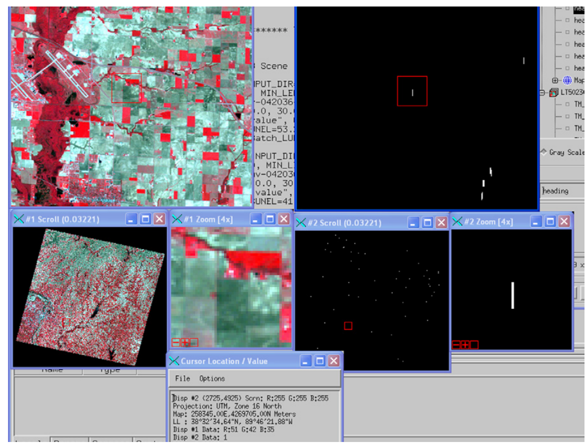

Figure 105. B10 Software Output

Visit 11—B13: 38° 22' 52.29" N 89° 48' 3.21" W, 180|360

B14: 38° 22' 54.14" N 89° 46' 4.61" W, 180|360

B14 was very good. The STT representative did not find OLSs to match them. There was high corn on the site at the time of the visit; so the team could not see the field well.

Figure 106. Map of B13 and B14

Figure 107. B14 (a)
Note: Planted with Corn

Figure 108. B14 (b) Another View

Figure 109. B14 (c) A Different Perspective

Figure 110. B14 (d)

Figure 111. B14 (e)

Figure 112. B14 (f)

Figure 113. B14 (g)

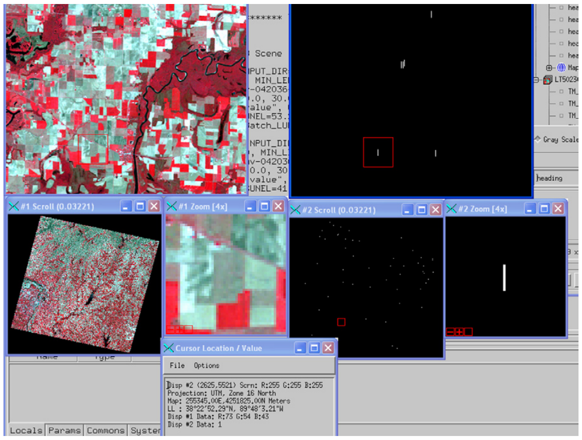

Figure 114. B13 Software Output

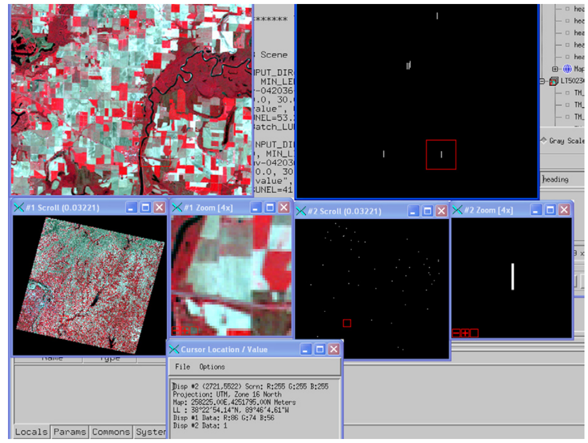

Figure 115. B14 Software Output

Visit 12—J2: 38° 16' 43.1" N 89° 45' 57" W, 180, 3800 ft.

The Boeing software did not find this one. This was the third failure of the STT-designated landing sites. Power lines and telephone lines as well as rolling terrain and vegetation are reasons it was not considered viable. The Boeing software did not designate it for these reasons.

Figure 116. J2 Shown on Map

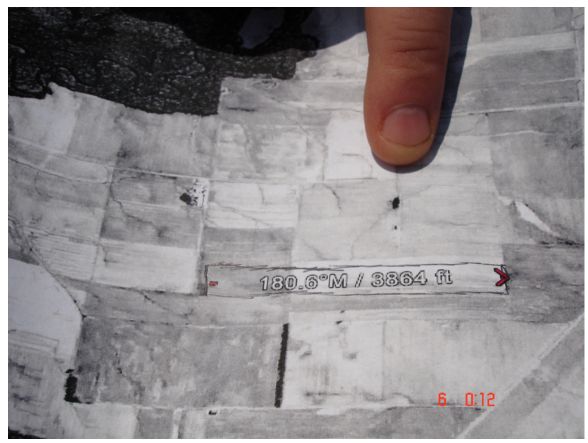

Figure 117. J2 Orthophotoquad

Figure 118. J2 (a) Rolling Terrain

Figure 119. J2 (b) A Different View

Figure 120. J2 (c)

Figure 121. J2 (d)

Figure 122. J2 (e) Another View

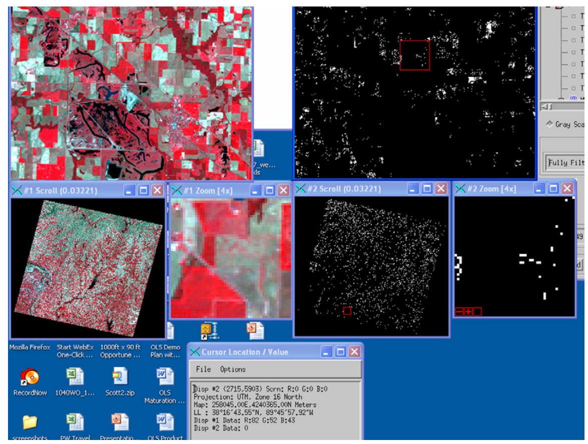

Figure 123. J2 Software Output

Visit 13—J14: 38°16'42.8" N 89°42'32.3" W, 109°, 3800 ft.

Lehr Road has a suitable Landing Zone. The Software ruled it out because of vegetation (a winter wheat crop in April). A solution might include (1) reducing the vegetation threshold or (2) georectification (~200 yards off).

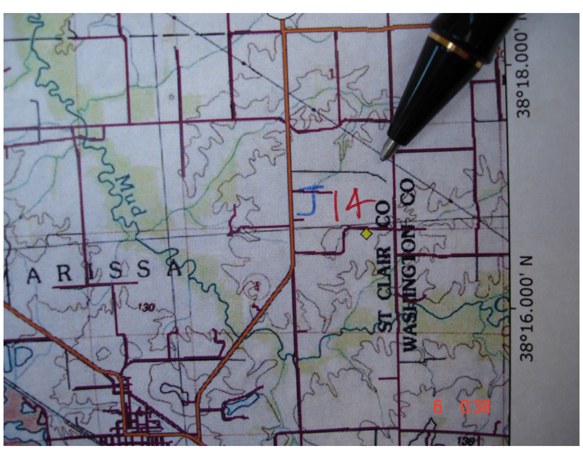

Figure 124. Map of J14

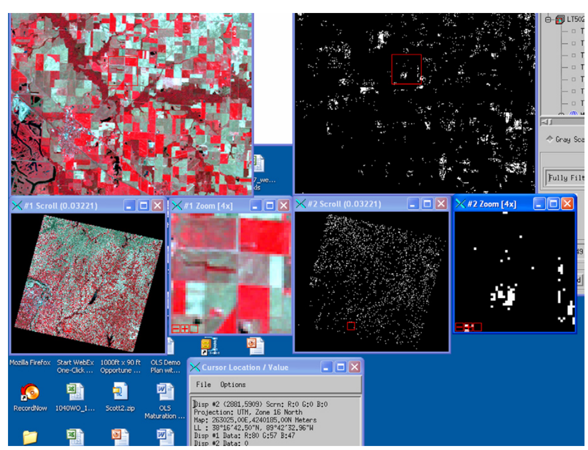

Figure 125. J14

Note: Software Illustrates Georegistration Problem

Figure 126. J14 (a)

Figure 127. J14 (b) A Slightly Different View

Figure 128. J14 (c) Another view

Figure 129. J14 (d)

Figure 130. J14 (e)

Visit 14—B16: 38° 17' 34.78" N 89° 43' 26.76" W, 180|360

B16 is a good Landing Zone space, and it is very wide. There is a cluster of suitable landing zones five pixels in width, indicating numerous potential sites.

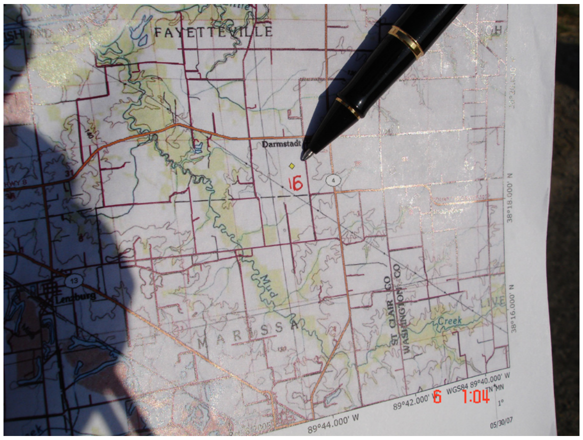

Figure 131. B16 As Shown on Map

Figure 132. B16 (a)

Figure 133. B16 (b) Different Perspective

Figure 134. B16 (c)

Figure 135. B16 (d)

Figure 136. B16 (e)

Figure 137. B16 (f) Another View

Figure 138. B16 (g)

Figure 139. B16 (h)

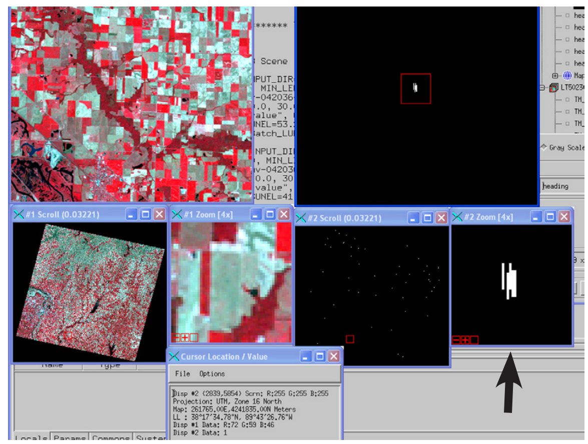

Figure 140. B16
Note: Arrow Indicates Cluster of LZs in Software Output

Visit 15—B37: 38º20'49.33" N 89º48'18.24" W, 90|270

B 37 is in the Kaskaskia River flood plain. The team scored this as a good site based on what the software was designed to do. The site avoided power lines because it was beside the road. However, per the referee, the site is surrounded by trees. It was suggested that future versions of the software should consider approach and departure space, in which case this site might no longer be considered suitable.

Figure 141. B37 Shown on Map

Figure 142. B37 (a) A Short Approach

Figure 143. B37 (b)

Figure 144. B37 (c)

Note: Arrow Indicates Fence in Lower Right Corner.

Figure 145. B37 (d)

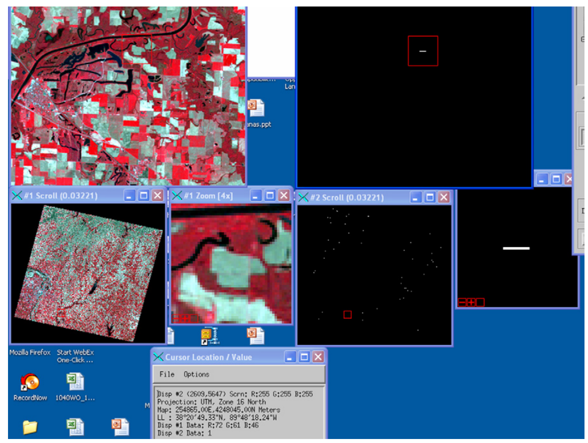

Figure 146. B37 Software Output

Visit 16—B36: 38° 23' 16.01" N 89° 54' 27.38" W, 90|270°

B36 is an east-west site. The team could not get really close, but it looks good. The team photographed one OLS that starts near the big barn and one that starts beyond the cornfield.

Figure 147. B36 Shown on Map

Figure 148. B36

Figure 149. B36 Another View

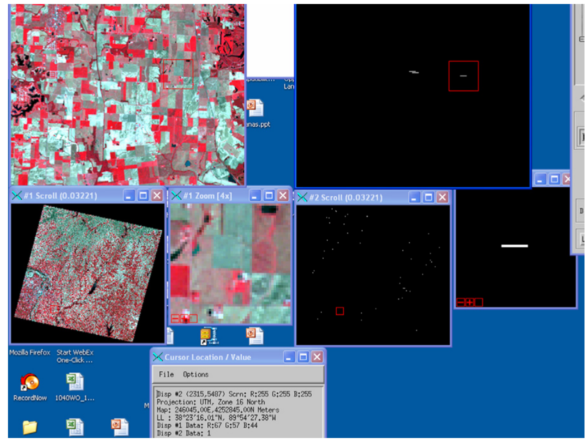

Figure 150. B36 Software Output

Visit 17—B35: 38°24'37.58" N 89°48'35.72" W, 90|270°.

B35 was a very good site. There were also others on the other side. While searching for B35, the team went past a flooded strip mining area which the software did not identify as OLSs.

Figure 151. B35 Shown on Map

Figure 152. B35 (a)

Figure 153. B35 (b)

Figure 154. B35 (c) Another View

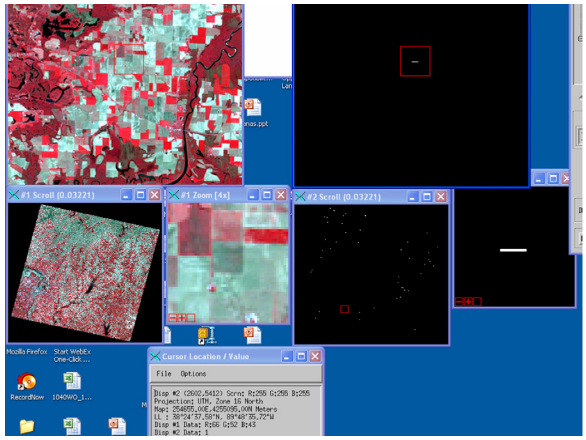

Figure 155. B35 Software Output

5. Conclusions

The inspection team members viewed 40 sites during the day on 5 June 2007. In general, the software was judged to have performed quite well. Of the 23 "B" sites reviewed, all were considered potentially acceptable OLSs, although they were shorter in length than what was initially sought. The Inspection method identified 17 possible runways that were at least 3500 feet long, of which three were rejected. Two had become construction sites in the period between the taking of the satellite images and the inspection. Another was considered unsuitable because of the presence of power lines and a ditch. Adjusting the software in order to require a longer runway length might have ruled out some of the "B" sites, but, in accordance with the requirements for this demonstration, all of the software-designated sites proved acceptable. Based on this sampling and its results, it would appear that the OLS runway-finding software could be used to identify potential OLSs at least as well as the methods currently being used by STTs, given that the software database is properly maintained.

It was agreed that the objective of the OLS Software Demonstration and Validation Program would be shown to have been met if the team were to demonstrate that the documented exit criteria were met. In terms of KPP P01: Capability to identify suitable landing sites in a specified area, given that suitable landing sites exist, the runway-finding software identified 40 sites, whereas an individual using the standard manual method identified only 17 sites in the region. It could be argued that the software scored 235 percent. While the exact score is unknown, there is agreement that the exit criterion of at least 50 percent was certainly exceeded, and it could be argued that the objective of 100 percent was met. The lesson learned is that properly defining the measurand and the method of collecting the data to support quantification against that measurand is important. P03, Incidence of false positives was 0, meeting the objective. This result exceeded expectations.

The performance of the software vastly exceeded the exit criteria. Moreover, it met the stretch goals established in the Demonstration Plan.

Future steps may include further scientific investigation and refinement of the software module. The OLS Project Team continues to explore potential additional uses for the OLS software and its capabilities. Other issues to be resolved include whether it should be distributed as a package or a service, and who should maintain the database upon which it relies, adding to and/or upgrading that database as situations change. Resolving the issue of georegistration is a necessary step for possible future development under the OLS Technology Maturation Plan, AFRL-RB-WP-TR-2008-3064 (AD number B336859). A more complete view of recommendations to move toward an OLS Initial Operational Capability can be found in that document.

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACRONYM	DESCRIPTION
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AFRL/RB	Air Vehicles Directorate of AFRL
AFRL/RBC	Control Sciences Dibision of AFRL/RB
AFRL/RBCC	Control Systems Development & Application Branch of AFRL/RBC
AMC	Air Mobility Command
DTED	Digital Topographic Elevation Data
ERDC-CRREL	Engineer Research and Development Center-Cold Regions Research and Development Center (Army)
GDAIS	General Dynamics Advanced Information Systems
IR	Infrared (spectral region)
KPP	Key Performance Parameter
LANDSAT	Land Remote Sensing Satellite System
LZ	Landing Zone
OLS	Opportune Landing Site
STT	Special Tactics Team
Tech Mat	Technology Maturation (Plan)